CLAIMS

What is claimed is:

1. A method of determining a cardiac response to a pacing pulse, comprising:

providing a plurality of electrodes electrically coupled to a heart;

delivering the pacing pulse to the heart using a first electrode combination;

sensing a cardiac signal following the pacing pulse using a second electrode combination; and

classifying the cardiac response to the pacing pulse as one of a captured response, a non-captured response, and a fusion/pseudofusion beat using the sensed cardiac signal.

2. The method of claim 1, further comprising:

detecting noise on the cardiac signal; and

canceling the classification of the cardiac response based on the detection of noise.

3. The method of claim 1, wherein:

sensing the cardiac signal comprises detecting a characteristic of the cardiac signal; and

classifying the cardiac response comprises:

comparing the detected characteristic to a reference; and

classifying the cardiac response based on the comparison.

4. The method of claim 3, wherein:

detecting the characteristic of the cardiac signal comprises detecting an amplitude of the cardiac signal; and

comparing the detected characteristic to a reference comprises comparing the detected amplitude to an amplitude reference.

5. The method of claim 3, wherein:

detecting the characteristic comprises detecting a slope of the cardiac signal; and

comparing the detected characteristic to a reference comprises comparing the detected slope to a slope reference.

6. The method of claim 3, wherein:

detecting the characteristic of the cardiac signal comprises detecting a curvature of the cardiac signal; and

comparing the detected characteristic to a reference comprises comparing the detected curvature to a curvature reference.

7. The method of claim 3, wherein:

detecting the characteristic of the cardiac signal comprises detecting a peak width of the cardiac signal; and

comparing the detected characteristic to a reference comprises comparing the detected peak width to a peak width reference.

8. The method of claim 3, wherein:

detecting the characteristic of the cardiac signal comprises detecting one or more feature points of the cardiac signal; and

comparing the detected characteristic to a reference comprises:

providing a template; and

comparing the detected feature points to the template.

9. The method of claim 1, wherein:

delivering the pacing pulse to the heart using a first electrode combination comprises delivering the pacing pulse to using a near-field vector; and

sensing the cardiac signal following the pacing pulse using a second electrode combination comprises sensing the cardiac signal using a far-field vector.

10. The method of claim 1, wherein:

delivering the pacing pulse to the heart using a first electrode combination comprises delivering the pacing pulse using a rate channel vector; and

sensing the cardiac signal following the pacing pulse using a second electrode combination comprises sensing the cardiac signal using a shock channel vector.

11. The method of claim 1, wherein:

delivering the pacing pulse to the heart using a first electrode combination comprises delivering the pacing pulse to a ventricle; and

sensing the cardiac signal following the pacing pulse using a second electrode combination comprises sensing a cardiac signal from the ventricle.

12. The method of claim 1, wherein:

delivering the pacing pulse to the heart comprises delivering the pacing pulse to one ventricle using the first electrode combination; and

sensing the cardiac signal following the pacing pulse comprises sensing the cardiac signal using at least one electrode disposed in the other ventricle.

13. The method of claim 1, wherein:

delivering the pacing pulse to the heart comprises delivering the pacing pulse to an atrium using the first electrode combination; and

sensing the cardiac signal following the pacing pulse comprises sensing a cardiac signal using the second electrode combination.

14. The method of claim 1, wherein:

delivering the pacing pulse to the heart comprises delivering the pacing pulse to one atrium using the first electrode combination; and

sensing the cardiac signal following the pacing pulse comprises sensing a cardiac signal using at least one electrode disposed in the other atrium.

15. A method of determining a cardiac response to a pacing pulse, comprising:

providing a plurality of electrodes electrically coupled to a heart;

delivering the pacing pulse to the heart using a first electrode combination;

sensing a cardiac signal following the pacing pulse using a second electrode combination; and

classifying the cardiac response to the pacing pulse as one of least three cardiac response types using the sensed cardiac signal.

16. The method of claim 15, further comprising:

detecting noise on the cardiac signal; and

canceling the classification of the cardiac response based on the detection of noise.

17. The method of claim 15, wherein classifying the cardiac response as one of at least three cardiac response types comprises classifying the cardiac response type as a captured response.

18. The method of claim 15, wherein classifying the cardiac response as one of at least three cardiac response types comprises classifying the cardiac response type as a non-captured response.

19. The method of claim 15, wherein classifying the cardiac response as one of at least three cardiac response types comprises classifying the cardiac response type as a fusion/pseudofusion beat.

20. The method of claim 15, wherein classifying the cardiac response as one of at least three cardiac response types comprises classifying the cardiac response type as a near non-captured response.

21. The method of claim 15, wherein classifying the cardiac response as one of at least three cardiac response types comprises classifying the cardiac response type as a non-captured response added to an intrinsic beat.

22. The method of claim 15, wherein:

sensing the cardiac signal comprises detecting a characteristic of the cardiac signal; and

classifying the cardiac response comprises:

comparing the detected characteristic to a reference; and

classifying the cardiac response based on the comparison.

23. The method of claim 15, wherein:

delivering the pacing pulse to the heart using a first electrode combination comprises delivering the pacing pulse to a combination of electrodes associated with a near-field vector; and

sensing the cardiac signal following the pacing pulse using a second electrode combination comprises sensing the cardiac signal using a far-field vector.

24. A method for classifying a cardiac pacing response, comprising:

providing a plurality of electrodes electrically coupled to a heart;

delivering the pacing pulse to the heart using a first electrode combination;

sensing a cardiac signal following the pacing pulse using a second electrode combination;

defining a plurality of classification windows relative to and subsequent to the pacing pulse;

detecting a characteristic of the cardiac signal within a particular classification window; and

classifying the cardiac response to the pacing pulse based on the detected characteristic and the particular classification window.

25. The method of claim 24, wherein defining the plurality of classification windows comprises defining one or more classification windows associated with a captured response.

26. The method of claim 24, wherein defining the plurality of classification windows comprises defining one or more classification windows associated with a non-captured response.

27. The method of claim 24, wherein defining the plurality of classification windows comprises defining one or more classification windows associated with a fusion/pseudofusion response.

28. The method of claim 24, wherein defining the plurality of classification windows comprises:

defining a first classification window based on a characteristic of a captured response; and

defining one or more additional classification windows in relation to the first classification window.

29. The method of claim 24, wherein classifying the cardiac response based on the detected characteristic and the particular classification window comprises:

comparing the characteristic of the cardiac signal to a reference associated with the particular classification window; and

classifying the cardiac response based on the comparison.

30. The method of claim 29, wherein comparing the characteristic of the cardiac signal to the reference associated with the particular classification window comprises comparing a peak of the cardiac signal to a peak reference.

31. The method of claim 29, wherein comparing the characteristic of the cardiac signal to the reference comprises comparing a slope of the cardiac signal to a slope reference.

32. The method of claim 29, wherein comparing the characteristic of the cardiac signal to the reference associated with the particular classification window comprises comparing a curvature of the cardiac signal to a curvature reference.

33. The method of claim 29, wherein comparing the characteristic of the cardiac signal to the reference associated with the particular classification window comprises comparing a peak width of the cardiac signal to a peak width reference.

34. The method of claim 29, wherein comparing the characteristic of the cardiac signal to the reference associated with the particular classification window comprises comparing one or more features of the cardiac signal to a template.

35. A method of detecting a fusion/pseudofusion beat, comprising:

providing a plurality of electrodes electrically coupled to a heart;

delivering a pacing pulse to the heart using a first electrode combination;

sensing a cardiac signal following the pacing pulse using a second electrode combination; and

detecting the fusion/pseudofusion beat using the sensed cardiac signal.

36. The method of claim 35, wherein:

sensing the cardiac signal comprises detecting a characteristic of the cardiac signal; and

detecting the fusion/pseudofusion beat comprises:

comparing the detected characteristic to a reference; and

detecting the fusion/pseudofusion beat based on the comparison.

37. The method of claim 35, wherein:

delivering the pacing pulse to the heart using a first electrode combination comprises delivering the pacing pulse to using a near-field vector; and

sensing the cardiac signal following the pacing pulse using a second electrode combination comprises sensing the cardiac signal using a far-field vector.

38. The method of claim 35, wherein detecting the fusion/pseudofusion beat comprises:

defining a plurality of classification windows relative to and subsequent to the pacing pulse;

detecting a characteristic of the cardiac signal within a particular classification window; and

detecting the fusion/pseudofusion beat based on the detected characteristic and the particular classification window.

39. A medical device, comprising:

a plurality of electrodes electrically coupled to a heart;

a pulse delivery circuit configured to deliver a pacing pulse to a heart using a first electrode combination;

a sensing circuit configured to sense a cardiac signal following the pacing pulse using a second electrode combination; and

a control circuit, the control circuit coupled to the sensing circuit and configured to classify a cardiac response to the pacing pulse as one of at least three cardiac response types based on the sensed cardiac signal.

40. The device of claim 39, wherein the control circuit is further configured to detect the cardiac signal as a noisy signal and to cancel classification of the cardiac response based on the detection of noise.

41. The device of claim 39, wherein the control system is configured to define a plurality of classification windows relative to and subsequent to the pacing pulse, detect a characteristic of the cardiac signal within a particular classification window, and classify the cardiac response based on the detected characteristic and the particular classification window.

42. The device of claim 39, wherein:

the pulse delivery circuit is configured to deliver the pacing pulse using a near field electrode combination; and

the sensing circuit is configured to sense the cardiac signal using a far field electrode combination.

43. The device of claim 39, wherein:

the pulse delivery circuit is configured to delivery the pacing pulse using a rate channel electrode combination; and

the sensing circuit is configured to sense the cardiac signal using a shock channel electrode combination.

44. The device of claim 39, wherein:

the a plurality of electrodes includes a right ventricular pacing electrode, a right ventricular coil electrode, and a can electrode;

the pulse delivery circuit is configured to deliver the pacing pulse to the right ventricle using the right ventricular pacing electrode; and

the sensing circuit is configured to sense the cardiac signal using the right ventricular coil electrode and the can electrode.

44. The device of claim 39, wherein:

the a plurality of electrodes includes a right ventricular pacing electrode, a right ventricular coil electrode, a superior vena cava electrode, and a can electrode;

the pulse delivery circuit is configured to deliver the pacing pulse to the right ventricle using the right ventricular pacing electrode; and

the sensing circuit is configured to sense the cardiac signal using the right ventricular coil electrode and the superior vena cava electrode tied to the can electrode.

45. The device of claim 39, wherein:

the plurality of electrodes includes a right chamber pacing electrode and a left chamber sensing electrode;

the pulse delivery circuit is configured to deliver the pacing pulse to a right chamber using the right chamber pacing electrode; and

the sensing circuit is configured to sense the cardiac signal of the right chamber using the left chamber sensing electrode.

46. The device of claim 39, wherein:

the plurality of electrodes includes a left chamber pacing electrode and a right chamber sensing electrode;

the pulse delivery circuit is configured to deliver the pacing pulse to a left chamber using the left chamber pacing electrode; and

the sensing circuit is configured to sense the cardiac signal of the left chamber using the right chamber sensing electrode.

47. The device of claim 39, wherein:

the plurality of electrodes includes a left ventricular pacing electrode and first and second right ventricular electrodes;

the pulse delivery circuit is configured to deliver the pacing pulse to a left ventricle using the left ventricular pacing electrode; and

the sensing circuit is configured to sense the cardiac signal of the left ventricle using the first and second right ventricular electrodes.

48. The device of claim 39, wherein:

the plurality of electrodes includes first and second right atrial electrodes;

the pulse delivery circuit is configured to deliver the pacing pulse to the right atrium using the first right atrial electrode; and

the sensing circuit is configured to sense the cardiac signal using the second right atrial electrode.

50. The device of claim 39, wherein the pulse delivery circuit further comprises a coupling capacitor through which the pacing pulse is delivered.

51. The device of claim 50, wherein the coupling capacitor has a value in a range of about 2 microfarads to about 22 microfarads.

52. A medical device, comprising:

a plurality of electrodes electrically coupled to a heart;

a pulse delivery circuit and configured to deliver a pacing pulse to a heart using a first electrode combination;

a sensing circuit and configured to sense a cardiac signal following the pacing pulse using a second electrode combination; and

a control circuit, the control circuit coupled to the sensing circuit and configured to detect a fusion/pseudofusion beat based on the sensed cardiac signal.

53. The device of claim 52, wherein the control circuit is further configured to detect the cardiac signal as a noisy signal and to cancel detection of the fusion/pseudofusion beat based on the detection of noise.

54. The device of claim 52, wherein:

the pulse delivery circuit is configured to deliver the pacing pulse using a rate channel vector; and

the sensing circuit is configured to sense the cardiac signal following the pacing pulse using a shock channel vector.

55. The device of claim 52, wherein:

the pulse delivery circuit is configured to deliver the pacing pulse using an electrode combination associated with a near-field vector; and

the sensing circuit is configured to sense the cardiac signal following the pacing pulse using a far-field vector.

56. The device of claim 52, wherein the control system is configured to define a plurality of classification windows relative to and subsequent to the pacing pulse, detect a characteristic of the cardiac signal within a particular classification window, and

detect the fusion/pseudofusion beat based on the detected characteristic and the particular classification window.

57. A medical device for classifying a cardiac response, comprising:

means for providing a plurality of electrodes electrically coupled to a heart;

means for delivering the pacing pulse to the heart using a first electrode combination;

means for sensing a cardiac signal following the pacing pulse using a second electrode combination; and

means for classifying the cardiac response to the pacing pulse as one of a captured response, a non-captured response, and a fusion/pseudofusion beat using the sensed cardiac signal.

58. The device of claim 57, further comprising:

means for detecting noise on the cardiac signal; and

means for canceling the classification of the cardiac response based on the detection of noise.

59. A medical device for determining a cardiac response to a pacing pulse, comprising:

means for providing a plurality of electrodes electrically coupled to a heart;

means for delivering the pacing pulse to the heart using a first electrode combination;

means for sensing a cardiac signal following the pacing pulse using a second electrode combination; and

means for classifying the cardiac response as one of least three cardiac response types using the sensed signal.

60. The device of claim 59, further comprising:

means for detecting noise; and

means for canceling the classification of the cardiac response based on the detection of noise.

61. A cardiac pacing response classification device, comprising:

means for providing a plurality of electrodes electrically coupled to a heart;

means for delivering the pacing pulse to the heart using a first electrode combination;

means for sensing a cardiac signal following the pacing pulse using a second electrode combination;

means for defining a plurality of classification windows relative to and subsequent to the pacing pulse;

means for detecting a characteristic of the cardiac signal within a particular classification window; and

means for classifying the cardiac response based on the detected characteristic and the particular classification window.

62. A system for detecting a fusion/pseudofusion beat, comprising:

means for providing a plurality of electrodes electrically coupled to a heart;

means for delivering a pacing pulse to the heart using a first electrode combination;

means for sensing a cardiac signal following the pacing pulse using a second electrode combination; and

means for detecting the fusion/pseudofusion beat using the sensed cardiac signal.